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Environmental Protection Department
Operations and Regulatory Affairs Division

LLNL Experimental Test Site 300

Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill

Annual Report for 2005

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Contents

Figures

Appendices

Tables

LLNL Experimental Test Site 300

Compliance Monitoring Program for the CERCLA-Closed Pit 6 Landfill

Annual Report 2005

Summary

This monitoring report is required by the *Post-Closure Plan for the Pit 6 Landfill Operable Unit, Lawrence Livermore National Laboratory Site 300* (Ferry *et al.* 1998). It summarizes combined fourth quarter (October to December) and annual post-closure compliance activities performed at the closed Pit 6 landfill during 2005. Results from quantitative analyses by state-certified analytical laboratories of chemical constituents of concern (COCs) in ground water samples are summarized in the report and listed in the appendices.

COC measurements made during the fourth quarter of 2005 do not differ significantly from past quarters. Historical analytical results for selected COCs monitored in ground water samples from detection monitoring program wells are presented as part of the annual report. The data do not contain evidence of a new release of COCs from Pit 6. A few COCs that were released to ground water from the landfill prior to its closure in 1998 continued to be detected including tritium, several volatile organic compounds (VOCs), and perchlorate. Elevation survey results of markers on the Pit 6 cap did not reveal any significant changes, other than minor impacts likely resulting from firefighting activities occurring during July 2005.

Introduction

Site 300 is the Lawrence Livermore National Laboratory (LLNL) Experimental Test Facility located in the Altamont Hills approximately 13 kilometers (8 miles) southwest of Tracy, California (**Figure 1**). Site 300 is owned by the United States Department of Energy (DOE) and is a 30.3 km^2 (11.8 mi^2) area site operated by the Regents of the University of California. The closed Pit 6 landfill is located within Site 300 near its southern boundary (**Figure 2**). A post-closure plan requiring quarterly and annual reports of compliance monitoring activities at the Pit 6 landfill (Ferry et al. 1998) was implemented during the second quarter of 1998.

Figure 1. Location of LLNL Site 300.

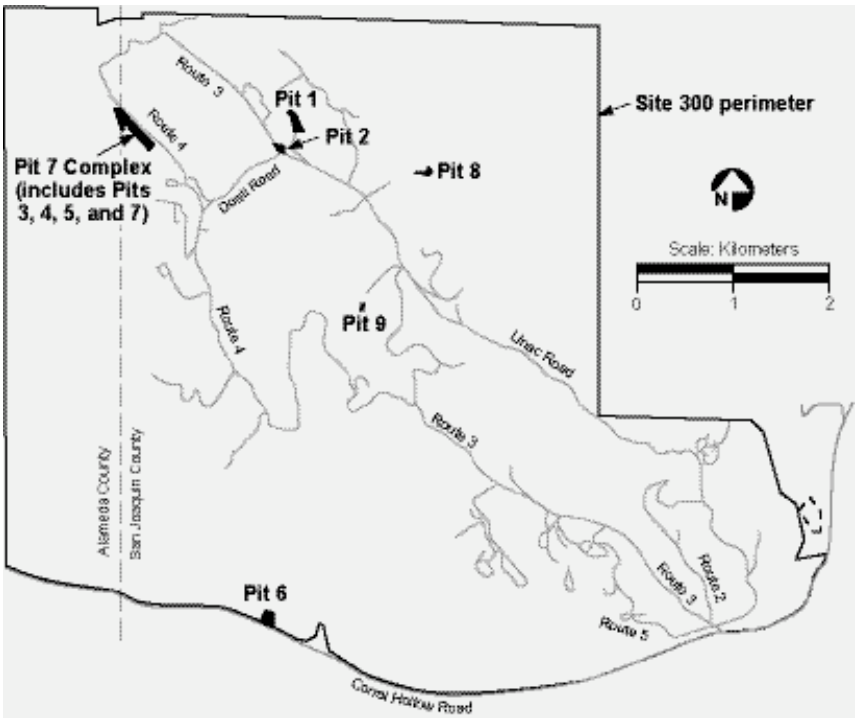

Figure 2. Location of Pit 6 at LLNL Site 300.

Figure 3 shows the locations of the wells that are used to monitor the ground water in the vicinity of the Pit 6 landfill, including upgradient wells, detection monitoring wells, and corrective action monitoring wells (Ferry *et al.* 1998). The northern limit of the Carnegie-Corral Hollow Fault zone extends beneath Pit 6 as shown in **Figure 3**. Ground water flows southeastward, following the inclination (dip) of the underlying sedimentary rocks. Depths to the water table range from 10 to 20 meters (m) (32.8 to 65.6 feet [ft]). Terrace deposit gravel within the fault zone beneath Pit 6 provides a channel for ground water to flow east-southeast, parallel to the Site 300 boundary fence line (Webster-Scholten 1994).

Monitoring program overview

The primary post-closure monitoring activity performed by LLNL at Pit 6 is the quarterly collection of ground water samples for chemical analyses. Field measurements of ground water physical parameters are collected at the time of sampling. Two ground water monitoring programs have been implemented at the Pit 6 landfill to ensure compliance with regulations. The Detection Monitoring Program (DMP) detects any new release of COCs to ground water from wastes buried in the Pit 6 landfill, while the Corrective Action Monitoring Program (CAMP) monitors the

movement and fate of historically-released COCs in the ground water. COCs, as defined by Title 23 of the *California Code of Regulations* (CCR), Chapter 15, are waste constituents, reaction products, and hazardous constituents that are reasonably expected to be in or derived from waste buried in the Pit 6 landfill.

Twenty-four COCs, including VOCs and radioisotopes, were identified initially for monitoring (Ferry *et al.* 1998). Perchlorate and nitrate were discovered subsequently in the ground water near Pit 6 during CERCLA site-wide surveys. Perchlorate was added to the COC list, and quarterly monitoring and reporting on it began during the third quarter of 2000. Since January 2003, an expanded set of CAMP wells (**Figure 3**) have been monitored for tritium activity, volatile organic compounds (VOCs), nitrate, and perchlorate. Additional changes to the monitoring program implemented since January 2003 are discussed in **Appendix D**.

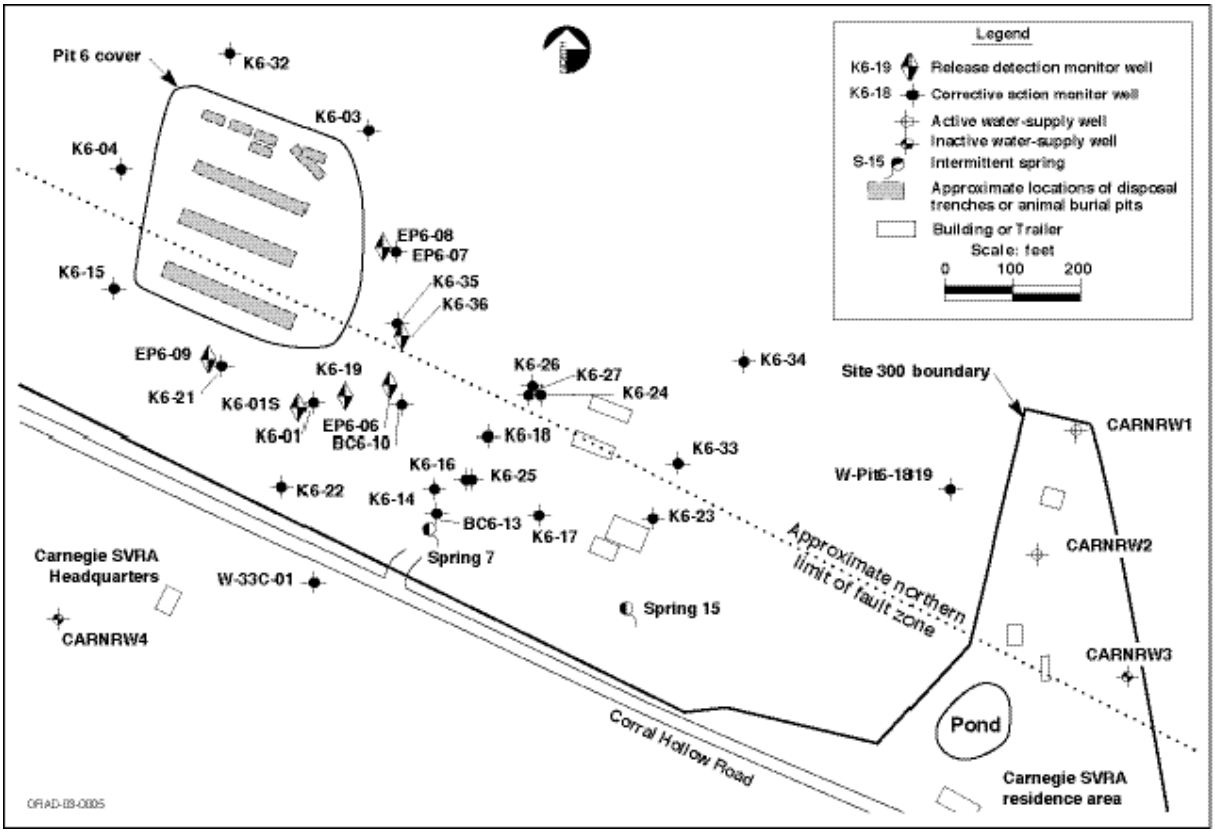

Figure 3. Locations of Pit 6 monitoring wells.

As required by DOE Order 241.1, our measurements are reported in *Système Internationale* (SI) units. The SI unit for radioactivity is the becquerel (Bq), equal to 1 nuclear disintegration per second. The more commonly used unit, picocurie (pCi), is equal to 1 nuclear disintegration per 27 seconds. As a convenience, MCLs for

radioactivity in drinking water are given in both becquerels per liter (Bq/L) and picocuries per liter (pCi/L) in **Table 1** below. Note that MCLs are provided for reference only, because this report does not involve wells used for potable domestic, livestock, or industrial water supply.

Table 1. MCLs for radioactivity in drinking water.

Radiological parameter	**MCL** (Bq/L)	**MCL** (pCi/L)
Gross alpha	0.555	15
Gross beta	1.85	50
Tritium	740	20,000
Radium (total)	0.185	5
Uranium (total)	0.74	20

DMP objective. The primary DMP objective is to detect any new release of COCs to ground water. Ground water is sampled quarterly from six wells located hydraulically downgradient of Pit 6 along the point of compliance. These wells are identified as EP6-06, EP6-08, EP6-09, K6-01S (K6-01 if K6-01S is dry), K6-19, and K6-36 in **Figure 3**. Water samples are sent to state-certified laboratories where they are analyzed quantitatively for the presence (or absence) of COCs (see **Appendix C**, **Table C-1** for the list of DMP COCs). Gross alpha and gross beta radioactivity measurements are used as surrogates for seven radionuclide COCs other than uranium and tritium. Additional field measurements of ground water general parameters are obtained quarterly at the time of sample collection.

Potential releases of COCs from Pit 6 are indicated by comparing analytical results for ground water samples with statistically-determined limits of concentration, called statistical limits, or SLs (see **Appendix C**, **Table C-1**, for the list of COCs and their respective SLs). If a COC measurement exceeds an SL, the measurement is investigated further to determine its validity. Consistent with state regulations, two independent ground water samples, called retest samples, are obtained at least one week apart from the associated monitoring well and analyzed for the suspect COC. If the COC is present in either sample at a concentration that exceeds the SL, then the initial analysis is deemed to be validated and it is reported as statistically significant evidence of a release. If neither retest sample measurement exceeds the SL, then the initial exceedance is not confirmed, and a release report is not made. Any further investigation of a COC is at the discretion of the Site 300 Remedial Project Managers (RPMs) and is conducted by LLNL under CERCLA.

CAMP objectives. The primary CAMP objectives are to: (1) evaluate the effectiveness of the corrective action, (2) evaluate natural attenuation of the ground water VOC and tritium plumes, (3) monitor perchlorate and nitrate in ground water, and (4) evaluate the need for implementing contingency actions. To accomplish the CAMP objectives, ground water measurements from the monitoring wells shown in **Figure 3** are evaluated on a quarterly basis as directed by the CAMP sampling plan.

Several VOCs, tritium, and perchlorate were released to ground water from Pit 6 prior to its closure. VOCs, primarily the solvents PCE and TCE, have been described and evaluated previously in the *Final Site-Wide Remedial Investigation Report, Lawrence Livermore National Laboratory Site 300* (Webster-Scholten 1994), the *Final Feasibility Study for the Pit 6 Operable Unit, Lawrence Livermore National Laboratory Site 300* (Devany *et al*. 1994), the *Addendum to the Pit 6 Engineering Evaluation/Cost Analysis, Lawrence Livermore National Laboratory, Site 300* (Berry 1996), the *Final Site-Wide Feasibility Study for Lawrence Livermore National Laboratory Site 300* (Ferry *et al*. 1999), and the *Interim Site-Wide Record of Decision for Lawrence Livermore National Laboratory Site 300* (DOE 2001).

In previous Compliance Monitoring Program reports for the Pit 6 Landfill, maps have been presented for TCE only. Starting in 2004, a new format for presenting CAMP VOC data was used to maintain consistency with the CERCLA Compliance Monitoring Report. In this report, the concentrations of all VOCs detected in ground water monitoring wells in the Pit 6 area have been summed and are presented as Total VOCs (TVOCs). The concentrations of individual compounds contributing to the TVOC concentration in each well sample from fourth quarter are included in **Appendix B**, **Table B-2**.

Tritium activity is above the background activity in ground water downgradient from Pit 6, suggesting that a localized tritium release occurred prior to pit closure (Ferry *et al*. 1998). Monitored natural attenuation is the interim remedial action selected for the tritium plume.

Additional post-closure activities for Pit 6 include: (1) inspection of the landfill by LLNL technical staff annually and following major storms; (2) an annual comprehensive inspection of the landfill by an independent state-certified Professional Engineer (PE); (3) an annual pit cap elevation survey; (4) repairs as necessary to maintain the integrity of the landfill cap, its water diversion system, and its network of monitoring wells; and (5) preparation of reports. Reports of post-closure activities are provided quarterly to the participating regulatory agencies for their information and use.

Quality Assurance

To ensure data quality, we work within the established Quality Assurance (QA) program of the LLNL Environmental Protection Department (EPD). We use protocols and procedures that cover all aspects of ground water sampling, sample tracking, and data management. These written protocols and procedures are contained in the *LLNL Livermore Site and Site 300 Environmental Restoration Project Standard Operating Procedures (SOPs)* (Dibley and Depue 2003), the *Environmental Monitoring Plan* (Woods 2002), and the *EPD Quality Assurance Management Plan* (Merrigan 2001). Data quality is assessed by the following four methods: (1) analytical results for the routine and duplicate samples are compared by the analysts responsible for this report, (2) field blank samples are submitted to the analytical laboratories together with the routine ground water samples for identical analyses, (3) equipment blanks are prepared and analyzed to ensure that sampling equipment is properly cleaned before use, and (4) when samples are collected for volatile organic compound (VOC) analysis, a trip blank (prepared at the analytical laboratory) is carried into the field. A summary of fourth quarter 2005 QA results may be found in **Appendix E, Table E-1**.

DMP summary for fourth quarter 2005

COC measurements for the DMP wells are listed in **Appendix A**, **Table A-1**. Field measurements of ground water parameters and laboratory measurement of total dissolved solids (TDS) for the DMP wells are listed in **Appendix A**, **Table A-2**. Data collected during the fourth quarter of 2005 do not differ significantly from past quarters (see Campbell and Blake 2005) and do not contain evidence of a new release of COCs from Pit 6. A few COCs that were released to ground water from the landfill prior its closure in 1998 continue to be detected, including tritium and a few volatile organic compounds (VOCs) (**Table A-1**).

The reporting limits provided by the analytical laboratory for EPA Methods 200.8:Be, 200.8:Hg, 601, and 624 have varied this quarter due to changes in the laboratory's data management systems. This has affected the reported non-detect concentrations for the following COCs: beryllium, mercury, benzene, 1,2-dichloroethane, cis-1,2-dichloroethene, ethylbenzene, methylene chloride, PCE, toluene, 1,1,1-trichlororthane, and total xylenes. In all these cases, the different reporting limits represent a practical quantitation limit (PQL) selected by the analytical laboratory, not a change in measured concentrations. We have been negotiating with the laboratory to address this issue.

As part of the annual report for 2005, gross alpha and gross beta activities for the entire historical record in DMP monitoring wells are presented (**Figure 4 and 5**). As stated in the Post-Closure Monitoring Plan, gross alpha and gross beta activities are measured as an indicator of the presence of radionuclides other than tritium and uranium (which are specifically monitored). Gross alpha activity is an indicator for americium-125 and thorium-232, while gross beta activity is an indicator for cobalt-60, cesium-137, sodium-22, strontium-90, and thallium-204. There have been a few isolated elevated activities exceeding monitoring well SLs, however, these results were either found to be errors or were not confirmed with analyses of resampled ground water.

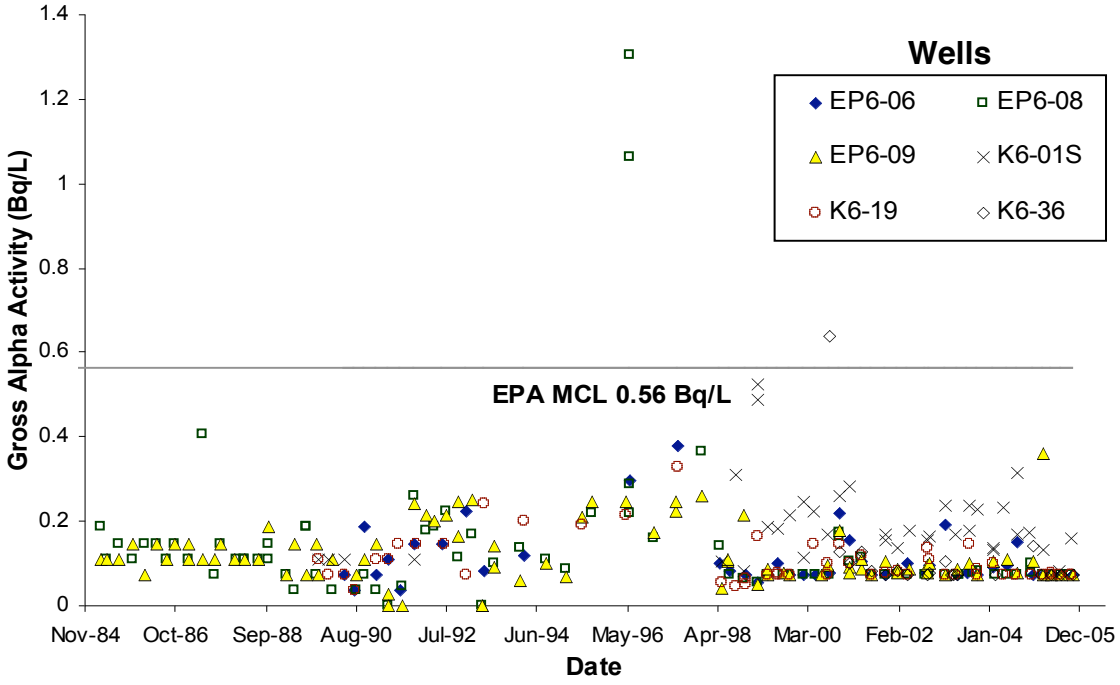

Figure 4. Historical ground water gross alpha activities (Bq/L) in the DMP monitoring wells at Site 300 Pit 6.

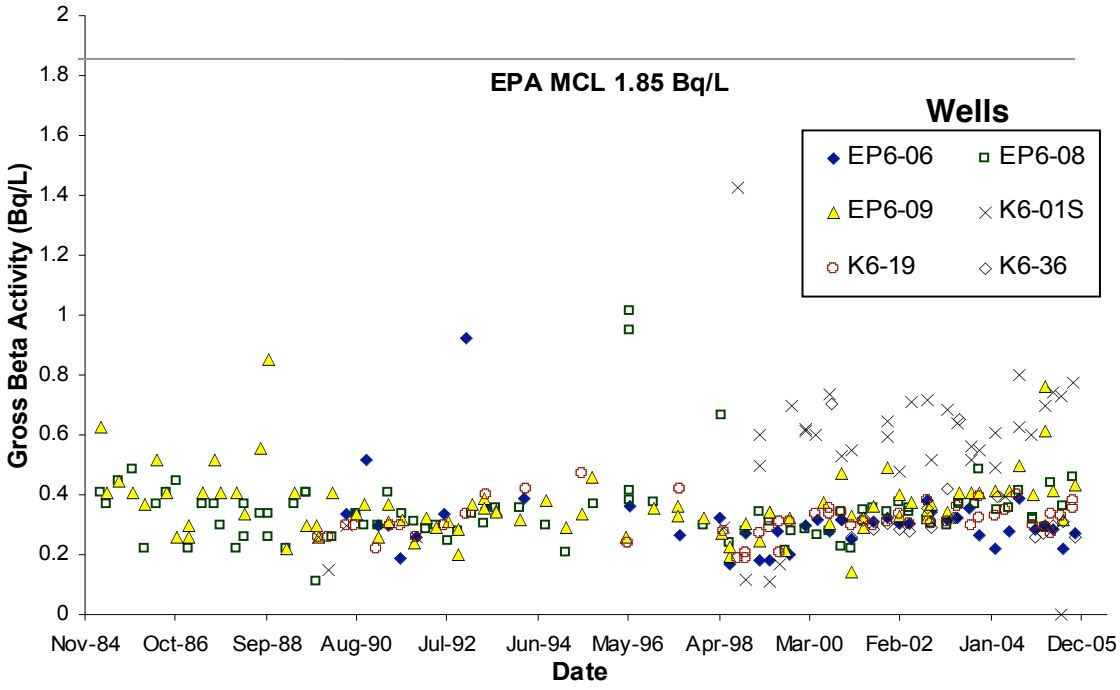

Figure 5. Historical ground water gross beta activities (Bq/L) in the DMP monitoring wells at Site 300 Pit 6.

Tritium activity continues to exceed the SL of 3.7 Bq/L (100 pCi/L) in ground water at downgradient DMP wells K6-19 (12.0 Bq/L [323 pCi/L]), K6-01S (10.3 Bq/L [278 pCi/L]), and K6-36 (57.7 Bq/L 1560 pCi/L]). For a more detailed account and map of the Pit 6 tritium activities and TVOC concentrations, see the following CAMP summary.

Historical values of TCE at monitoring wells K6-19 and EP6-09 have been plotted in **Figure 6**. These wells had higher concentrations of TCE in ground water in the past, and a decreasing trend can be observed in the data. For example, after TCE concentrations in well K6-19 ground water dropped below the SL (13 μg/L) in 1994, the SL has not been exceeded since. TCE concentrations continue to decline in ground water samples from this well.

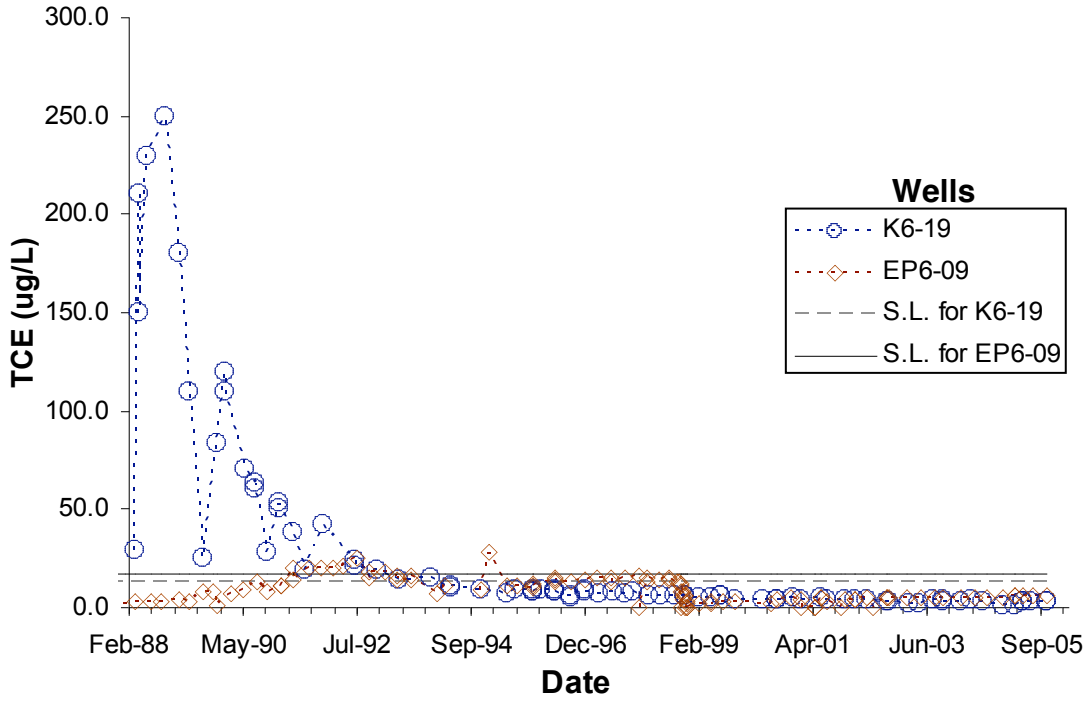

Figure 6. Historical ground water trichloroethene (TCE) concentrations (*µg*/L) in selected monitoring wells at Site 300 Pit 6.

In the past (before 2000), the highest perchlorate concentrations in Pit 6 ground water have been observed at DMP monitoring well K6-19. Perchlorate concentrations measured at this well and K6-36 since 2000, are presented in **Figure 7**. Since 2000, perchlorate concentrations at well K6-19 have fallen below the statistical limit (SL = 27.5 µg/L). For monitoring well K6-36, perchlorate concentrations have never exceeded the SL (14.4 µg/L). The limit of sensitivity (LOS) values are also plotted in the figure to define the limits of the analytical techniques. Data from other DMP monitoring wells (EP6-06, EP6-08, EP6-09, and K6-01S) have revealed occasional detections of perchlorate above the LOS. No new releases of perchlorate from Pit 6 are indicated by these data.

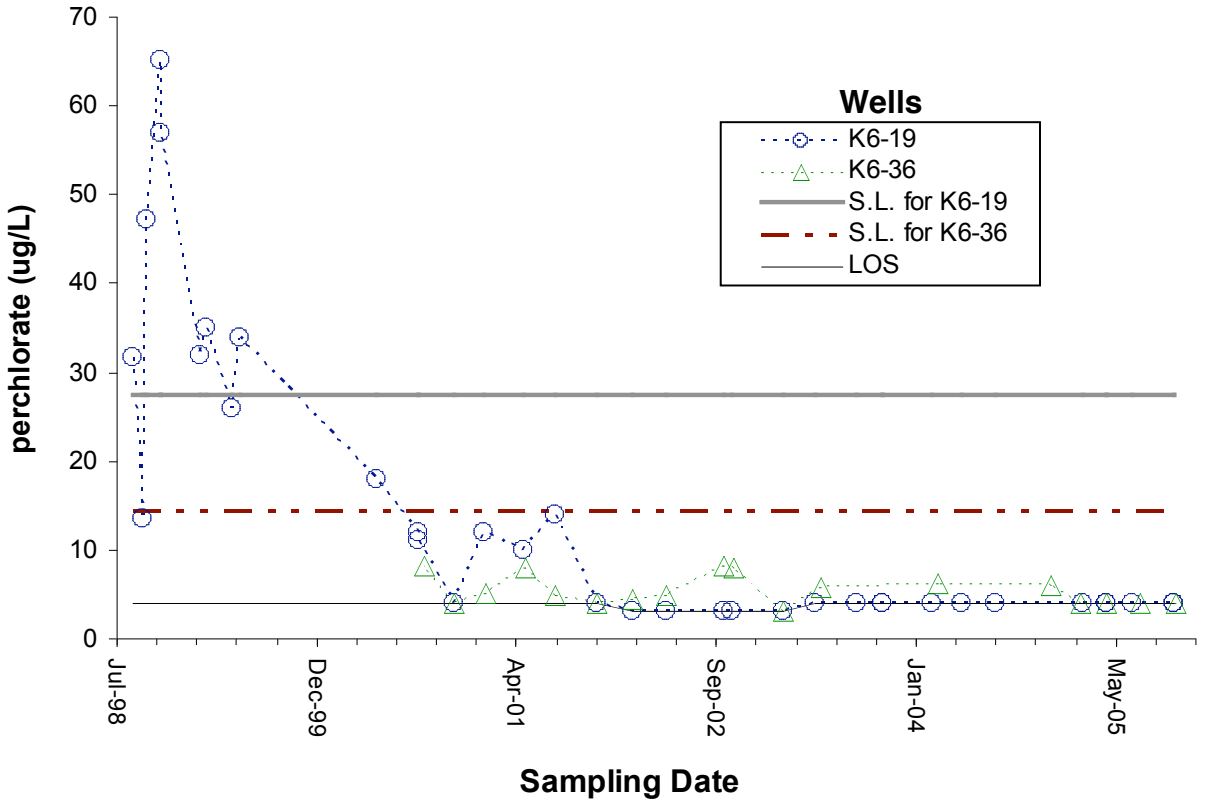

Figure 7. Historical ground water perchlorate concentrations (*µg*/L) in selected monitoring wells at Site 300 Pit 6.

CAMP summary for fourth quarter 2005

This section summarizes an analysis of ground water elevation and COC data collected during the fourth quarter of 2005. The primary COCs for the Pit 6 area are several VOCs and tritium (Ferry *et al*. 1998). Perchlorate and nitrate were subsequently detected at concentrations above the MCL in ground water samples from several Pit 6 monitoring wells during site-wide investigations by LLNL. Perchlorate was designated a secondary COC in 2000. Beginning in 2003, nitrate also became a secondary COC, and its occurrence in the ground water is discussed below. Ground water elevations for the fourth quarter of 2005 are listed in **Table B-1**. Detections of VOCs, tritium, perchlorate, and nitrate in ground water samples collected during the fourth quarter are listed in **Tables B-2, B-3,** and **B-4**, respectively.

Ground water elevations (GWE). **Figure 8** is a ground water elevation contour map for the fourth quarter of 2005. Ground water elevations beneath Pit 6 are approximately a minimum of 10 m (30 ft) below the buried waste trenches. During the three-month period between the third quarter of 2005 and the fourth quarter of 2005,

ground water elevations north of the Corral Hollow-Carnegie Fault Zone declined an average of 0.3 m (1 ft), while elevations within the fault zone remained relatively stable or declined slightly.

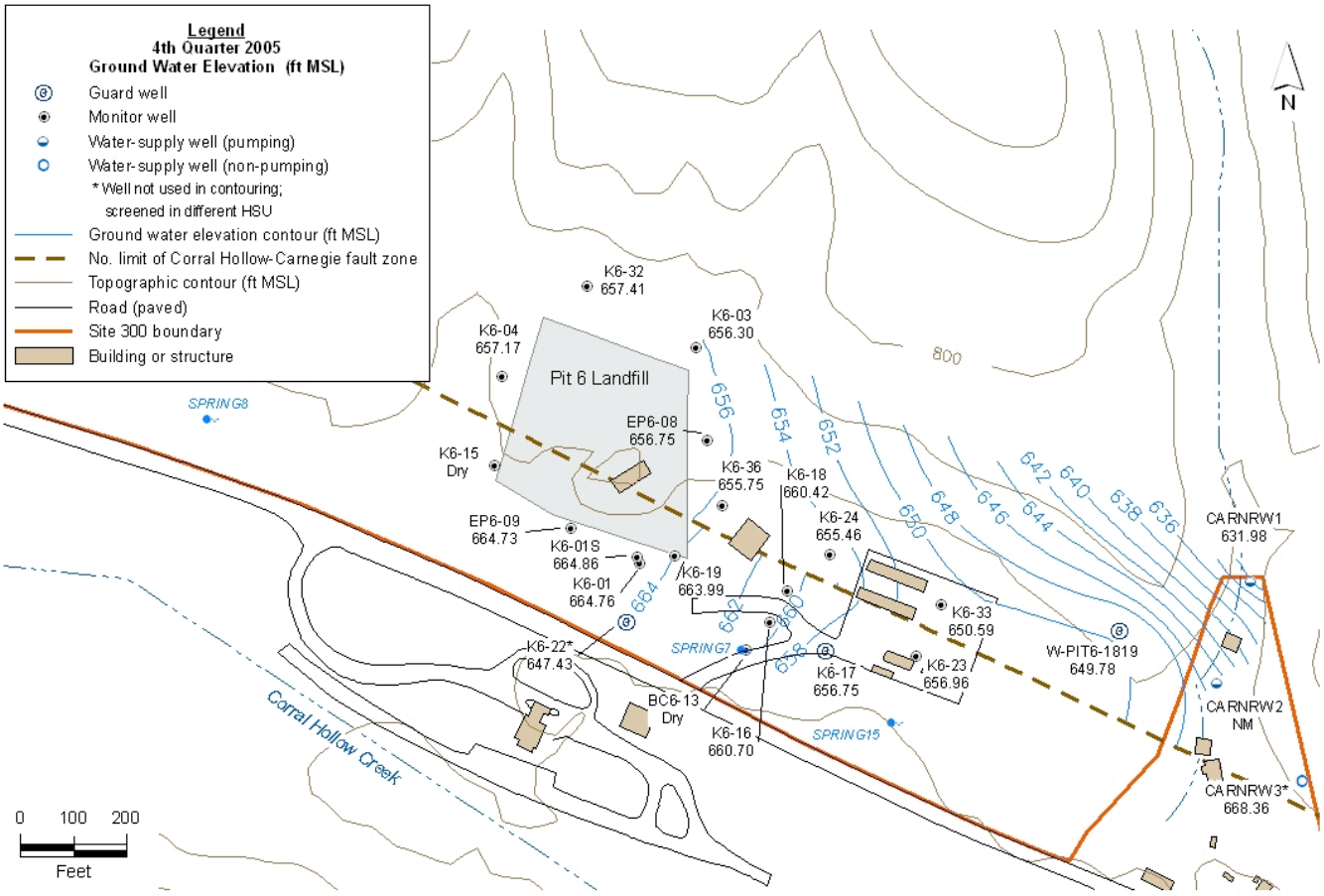

Figure 8. Ground water elevations (ft) for the first water-bearing zone at Site 300 Pit 6, fourth quarter 2005.

Figure 8 is consistent with previous potentiometric surface maps in that the general ground water flow direction is to the southeast. Within the fault zone, ground water flows to the southeast with a hydraulic gradient of approximately 0.03. North of the fault zone, ground water flows to the southeast with a hydraulic gradient of approximately 0.01. Fractures in the Neroly formation $Tnbs_1$ stratigraphic unit play a dominant role in ground water flow. A large component of the local ground water flow north of the fault is caused by pumping from wells CARNRW1 and CARNRW2. During this quarter, water elevations were measured while these wells were pumping, resulting in steeper contours in the northeast portion of the map that deflects towards the pumping wells. GWEs north of the fault zone are strongly influenced by pumping

from these wells, whereas GWEs within the fault zone to the south do not appear to be strongly influenced.

Ground water TVOC concentrations. Prior to the 2004 Annual Compliance Monitoring Report for the Pit 6 Landfill, maps were presented for TCE only. Starting with the 2004 Annual Report, a new format for presenting CAMP VOC data was used to maintain consistency with the CERCLA Compliance Monitoring Report. As shown in **Figure 9**, the concentrations of all VOCs detected in ground water samples collected during the fourth quarter 2005 in the Pit 6 area have been summed and are presented as Total VOCs (TVOCs). Except for chemicals that likely resulted from water treatment additives, TCE, PCE, and cis-1,2-DCE were the only VOCs detected at Pit 6 in ground water at concentrations above the method reporting limit of 0.5 µg/L for each compound during the fourth quarter of 2005. Although organic bromides and chlorides were detected in ground water samples from wells CARNRW2 and CARNRW3, these measured concentrations are likely the result of chlorination of the water from these wells.

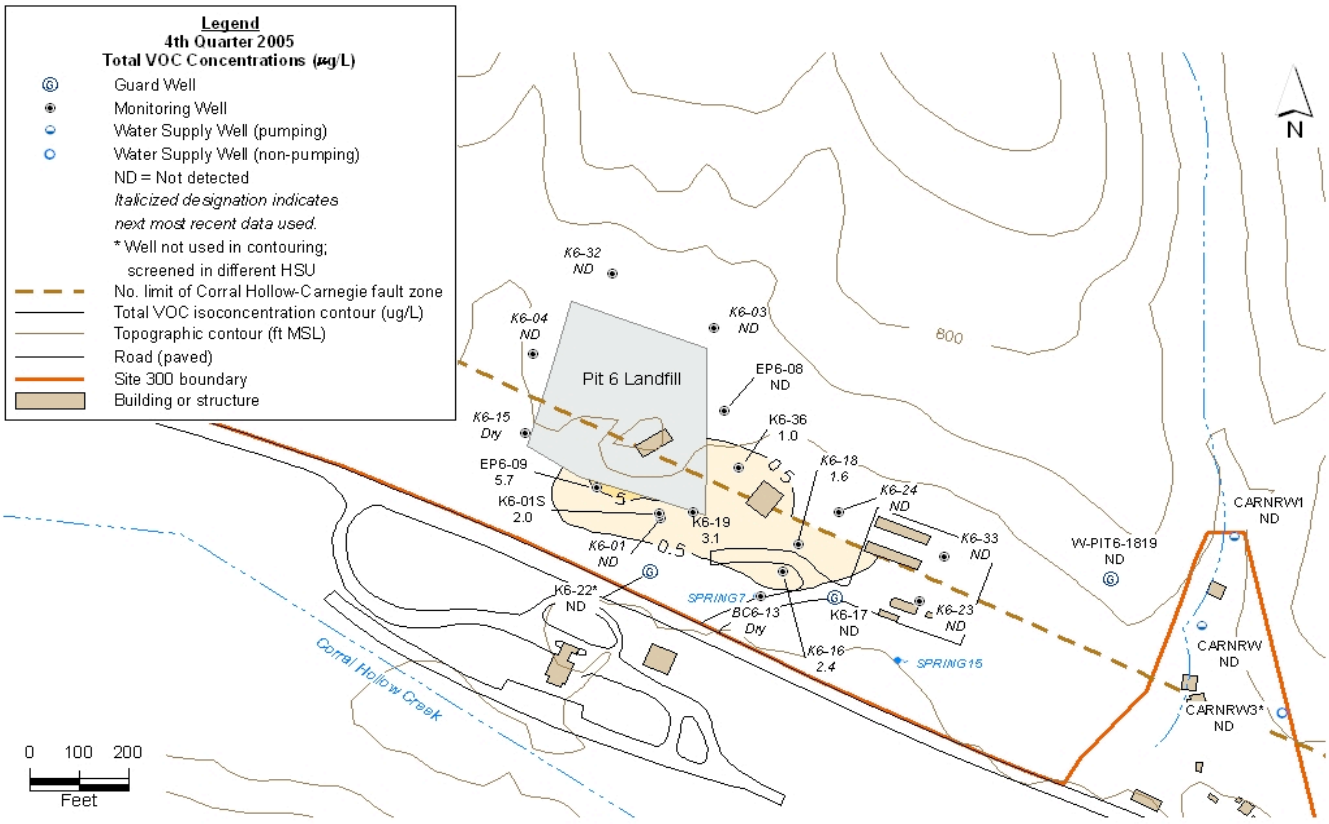

Figure 9. Ground water TVOC concentrations (µg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2005.

Figure 9 shows the distribution of TVOC concentrations in the shallow water-bearing zone (WBZ) for the fourth quarter of 2005. Within the fault zone, TVOCs were detected in ground water samples from monitor wells EP6-09, K6-01S, K6-16, K6-18, and K6-19. These wells define a narrow, elongated VOC plume that originates in the southeast portion of Pit 6. North of the fault, TVOCs were detected in ground water samples from monitor well K6-36. This well defines a localized VOC plume that originates in the east-central portion of Pit 6. As stated previously, organic bromides and chlorides probably arising from water treatment were found in samples from water-supply wells CARNRW2 and CARNRW3. The concentrations of individual VOCs in ground water samples collected during the fourth quarter of 2005 are listed in **Table B-2**.

Ground water TCE concentrations during the fourth quarter of 2005 were similar to those detected in previous quarters and years. The maximum ground water TCE concentration at Pit 6 this quarter was 5.7 μg/L in a ground water sample collected from well EP6-09. TCE concentrations are below the 5 μg/L MCL in all other wells. By year, the maximum TCE concentrations measured in ground water were 6.3 μg/L in 2000 (well K6-18), 5.4 μg/L in 2001 (well K6-19), 5.1 μg/L in 2002 (well EP6-09), 5.5 μg/L in 2003 (well EP6-09), 5.4 μg/L in 2004 (well EP6-09), and 6.4 μg/L in 2005 (well EP6-09). The monitoring data do not indicate any new release of TCE to ground water from Pit 6 during this quarter or this year.

Cis-1,2-DCE was detected in one ground water well (K6-01S) at Pit 6 at concentrations above the detection limit. During the fourth quarter 2005, the cis-1,2-DCE concentration in the ground water sample from well K6-01S was 2.0 μg/L. The previous detections (second and third quarters of 2005) for this well were 2.2 and 2.4 μg/L, respectively. Cis-1,2-DCE concentrations remain below the 6 μg/L MCL. The presence of cis-1,2-DCE likely represents the natural decomposition of TCE.

During 2005, PCE was detected in several ground water samples collected at Pit 6. During the fourth quarter, PCE was not detected in ground water samples from any wells at Pit 6. During the third quarter of 2005, 0.77 μg/L of PCE were detected in the ground water sample from well EP6-08. The previous detection (second quarter 2005) for this well was 0.97 μg/L. PCE was also detected in the third quarter 2005 ground water sample from well K6-36 at a concentration of 0.6 μg/L. Previous recent results for this well (K6-36) were 0.64 μg/L in second quarter 2005 and 0.68 μg/L in first quarter 2005.

Bromoform, bromodichloromethane, dibromochloromethane, and chloroform were detected in samples collected from CARNRW2 and CARNRW3, water-supply wells for the Carnegie State Vehicular Recreation Area Park (**Table B-2**). These constituents were not detected in ground water samples from any upgradient monitoring wells. The maximum total trihalomethane concentration detected was 27 μg/L in a sample from well CARNRW2, well below the MCL of 80 μg/L. It is likely that these organic halides detected in the well are the result of laboratory error, backflow of chlorinated water from the Carnegie chlorination system into the well, and/or direct chlorination of the well water by Carnegie Park staff.

Ground water tritium activity. **Figure 10** shows the areal distribution of tritium activity in ground water for the fourth quarter of 2005. During this quarter, tritium activity in excess of the 3.7 Bq/L (100 pCi/L) detection limit was found in ground water samples from wells K6-24, K6-33, K6-36 and W-PIT6-1819 north of the fault zone, and wells K6-01, K6-01S, K6-16, K6-18 and K6-19 within the fault zone. The highest tritium activity this quarter was measured in the ground water sample from well K6-36, north of the fault zone, at an activity of 57.7 Bq/L (1,560 pCi/L). Tritium activity in well K6-36 ground water was 62.2 Bq/L (1,680 pCi/L) during the fourth quarter of 2004, 57.3 Bq/L (1,550 pCi/L) during the first quarter of 2005, and 55.1 Bq/L (1,490 pCi/L) during the second quarter of 2005. Tritium activities in samples from this well (K6-36) have decreased from an historical maximum of 126.5 Bq/L (3,420 pCi/L) in 2003.

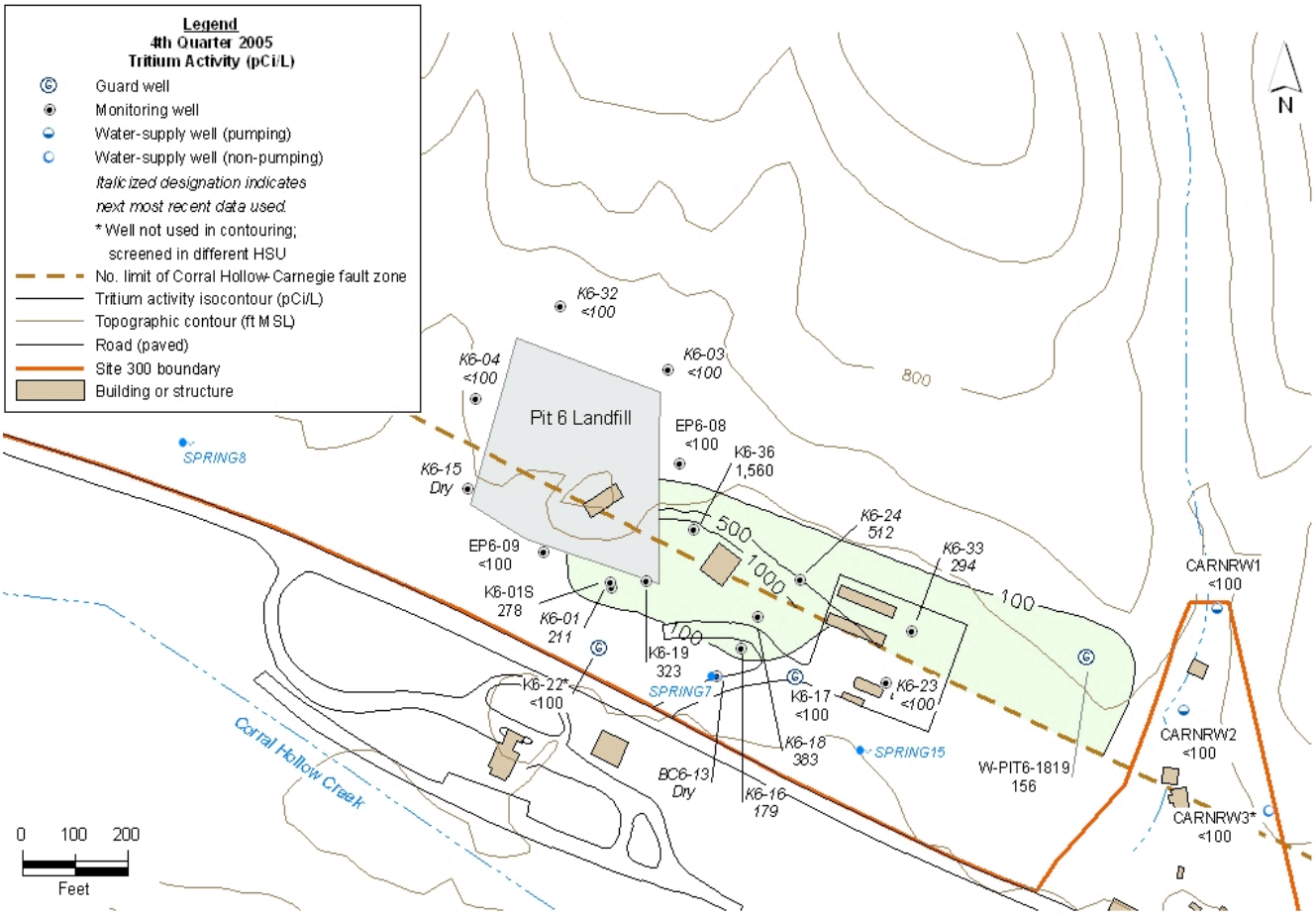

Figure 10. Ground water tritium activities (pCi/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2005.

Well W-Pit6-1819 is a guard well and is used to define the downgradient extent of the tritium plume. It is located about 30 m (100 ft) west of the Site 300 boundary with the Carnegie SVRA residence area and about 60 m (200 ft) west of the CARNRW1 and CARNRW2 water-supply wells (**Figure 10**). During the fourth quarter of 2005, the ground water at well W-Pit6-1819 contained 5.8 Bq/L (156 pCi/L) of tritium. The ground water from this well contained a tritium activity of 5.1 Bq/L (137 pCi/L) during the first quarter 2005, <3.7 Bq/L (<100 pCi/L) during the second quarter 2005, and 6.1 Bq/L (164 pCi/L) during the third quarter of 2005. Tritium activities were below the detection level of 3.7 Bq/L (100 pCi/L) in the monthly ground water samples obtained during the fourth quarter 2005 from the off-site CARNRW wells. Based on these analyses, the tritium plume appears to be relatively stable and tritium activities in wells within the plume are decreasing.

Ground water perchlorate concentrations. A map showing fourth quarter 2005 perchlorate concentrations in ground water samples collected from the shallow water-bearing zone is presented in **Figure 11**. Only one well yielded ground water samples showing perchlorate concentrations at or above the reporting limit of 4 μg/L. The only well that yielded perchlorate in ground water was EP6-09. The 4 μg/L of perchlorate was below the State Public Health Goal (PHG) of 6 μg/L. Last quarter, a ground water sample from this well yielded 6.9 μg/L of perchlorate. In the past, the maximum perchlorate concentrations in ground water have been measured at well K6-18 (15 μg/L in 2002, 14 μg/L in 2003, and 14 μg/L in 2004). During the first quarter of 2005, the perchlorate concentration in ground water from this well (K6-18) was less than 4 μg/L. Well K6-18 was not sampled during second, third, or fourth quarters of 2005. The available data indicate a decreasing trend in perchlorate concentrations in Pit 6 area ground water.

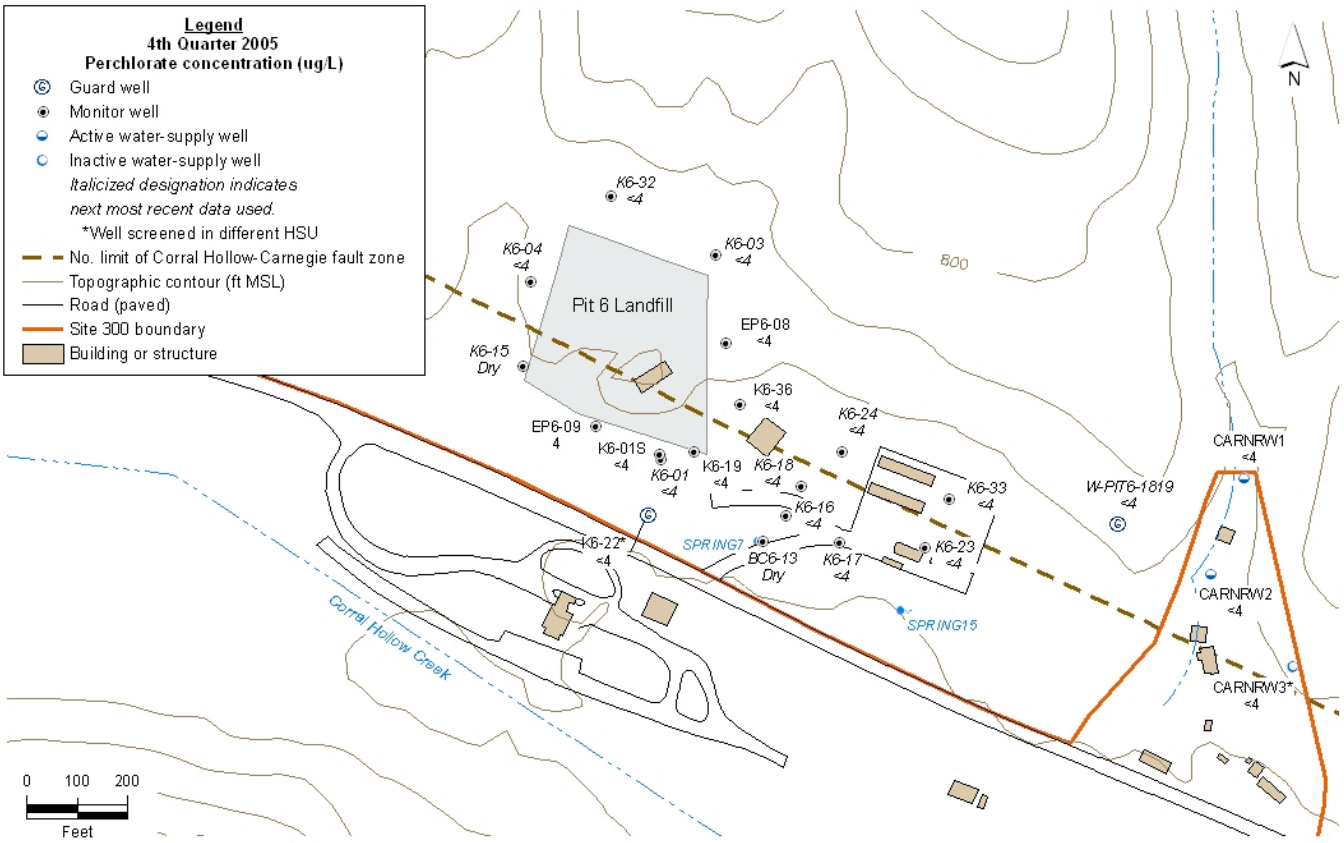

Figure 11. Ground water perchlorate concentrations (μg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2005.

Ground water nitrate concentrations. A map showing fourth quarter nitrate concentrations in the shallow water-bearing zone is presented in **Figure 12**. During the fourth quarter of 2005, nitrate was detected in ground water samples from monitor well, EP6-09, at a concentration of 3.2 μg/L. Last quarter, monitor wells EP6-09 and K6-36 yielded concentration of nitrate below the MCL of 45 mg/L. One monitor well at Pit 6, K6-23, consistently yields ground water nitrate concentrations in excess of the MCL. These ground water nitrate concentrations are the perennial maxima at Pit 6 and were 172, 165, and 200 mg/L in 2003, 2004, and 2005, respectively. The source of the nitrate in K6-23 ground water has not yet been established, but is potentially a septic system leachfield adjacent to the well. The fourth quarter 2005 ground water sample from water-supply well CARNRW1 contained 0.81 mg/L of nitrate. When detected, all ground water samples collected from the offsite water-supply wells at Pit 6 during 2005 contained nitrate at a fraction of the 45 mg/L MCL and within the range of background levels for nitrate.

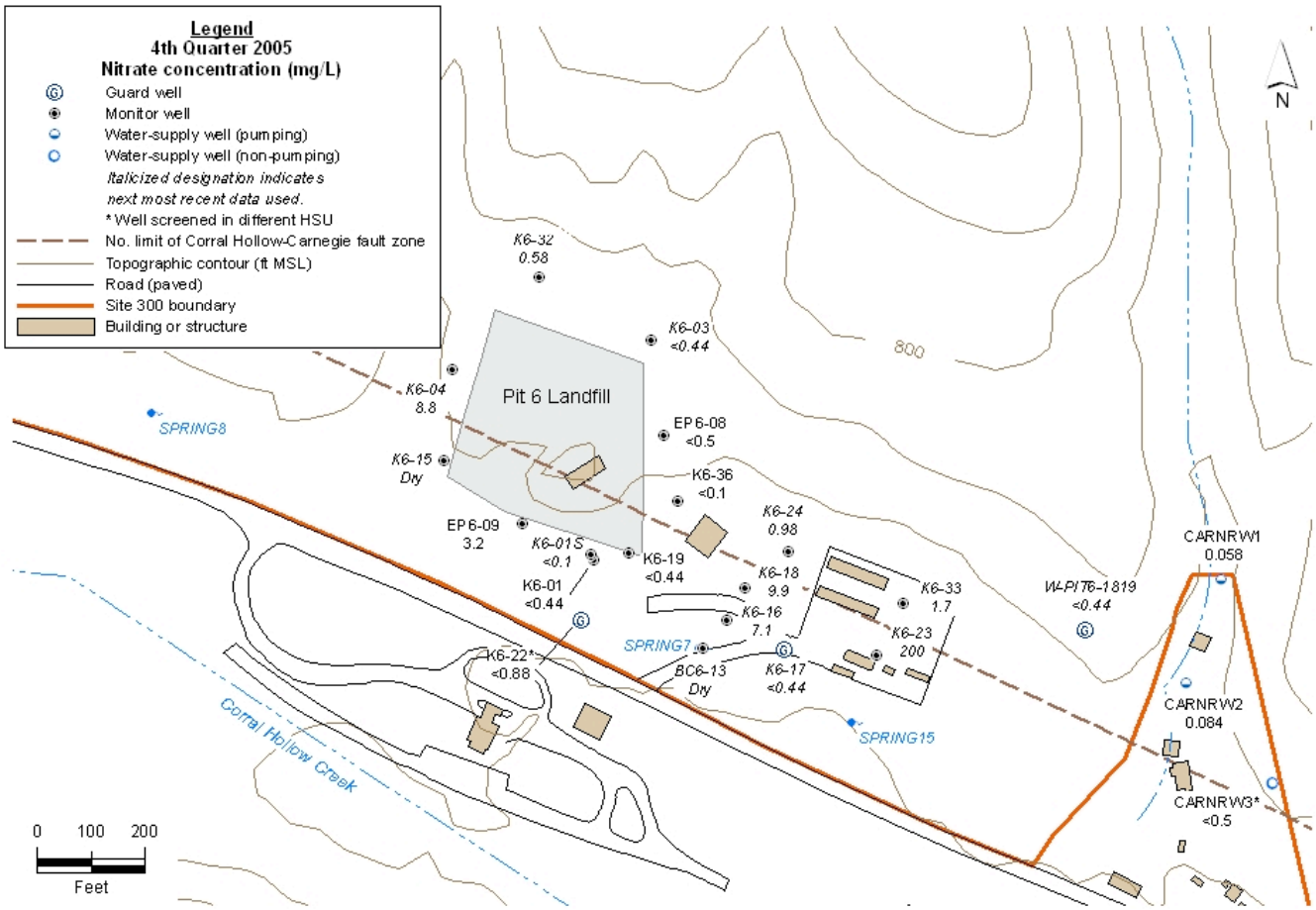

Figure 12. Ground water nitrate concentrations (mg/L) in the first water-bearing zone at Site 300 Pit 6, fourth quarter 2005.

Inspection and maintenance summary

Despite a wildfire, fire fighting activities, and normal weathering and bioturbation, our monitoring of the pit cap demonstrates that cap integrity has been maintained. The Annual Inspection by a licensed P.E. occurred prior to the fire at Site 300 on July 19, 2005, however, as reported during the third quarter, fire fighting activities did not have a significant impact on the cap and the necessary minor repairs have already been made (Campbell and Valett, 2005).

An annual elevation survey was completed on August 2, 2005 to detect any undue subsidence of the pit cover. LLNL surveyors measured the elevations of numerous fixed markers that had been installed on the pit cover in 1998 (**Appendix F**). A comparison of the year 2005 marker elevations with their baseline elevations established in 1998 shows a maximum marker elevation change during the seven year interval of 0.018 m (0.06 ft) and -0.027 m (-0.09 ft) (**Table F-1**). Measurements at one survey marker (A-5) were different during calendar year 2005 by -0.024 m (-0.08 ft), likely due to the fire fighting activities. It is unlikely that these small elevation changes have adversely affected the integrity of the pit cover.

References

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Abbreviations and acronyms

Bq	becquerel (international unit of radioactivity equal to 27 pCi)
CAMP	Corrective Action Monitoring Program
CC	control chart (statistical method)
CCR	California Code of Regulations
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Cis-1,2-DCE	cis-1,2-dichloroethene
CL	concentration limit (background concentration of a chemical)
COC	constituent of concern
CVRWQCB	Central Valley Regional Water Quality Control Board
DEHP	di(2-ethylhexyl)phthalate, bis(2-ethylhexyl)phthalate
DMP	Detection Monitoring Program
DOE	U.S. Department of Energy
DTSC	California Department of Toxic Substances Control
EPA	U.S. Environmental Protection Agency
EPD	LLNL Environmental Protection Department
ERD	LLNL Environmental Restoration Division
ft	foot (used as a measure of elevation above MSL)
GWD	ground water depth
GWE	ground water elevation in feet above MSL
km	kilometer
L	liter
LLNL	Lawrence Livermore National Laboratory
m	meter
MCL	maximum contaminant level (for drinking water)
MSL	mean sea level (datum for elevation measurements)
mg	milligram
μg	microgram
nd	none detected
PCB	polychlorinated biphenyl
PCE	perchloroethene, tetrachloroethene
pCi	picocurie (unit of radioactivity)
PE	Professional Engineer
PI	prediction interval (statistical method)

PQL	practical quantitation level
QA	quality assurance
RL	reporting limit (contractual concentration near zero)
RPM	Remedial Project Manager
Site 300	Experimental Test Facility, LLNL
SL	statistically determined concentration limit
SOP	standard operating procedure
TCE	trichloroethene
TDS	total dissolved solids
THM	trihalomethane
Tnbs1	Neroly Formation lower blue sandstone unit
TVOC	total volatile organic compound
VOC	volatile organic compound
WBZ	water bearing zone
yr	year

Appendix A

Tables of Ground Water Measurements

for Detection Monitoring Wells

Table A-1. Pit 6 post-closure monitoring plan constituents of concern (COCs) detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2005.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
Metals (μg/L)							
Beryllium	EP6-06	0.2	4	< 0.2	< 0.5 [(d)]	< 0.5	< 10 [(d)]
	EP6-08	0.2		< 0.2	< 0.5	< 0.5	< 10
	EP6-09	0.2		< 0.2	< 0.5	< 0.5	< 10
	K6-01S	0.2		< 0.2	< 0.5	< 0.2	< 0.2
	K6-19	0.2		< 0.2	< 0.5	< 0.2	< 0.2
	K6-36	0.2		< 0.5	< 0.5	< 0.2	< 2
Mercury	EP6-06	0.2	2	< 0.2	< 0.2	< 0.2	< 0.2
	EP6-08	0.2		< 0.2	< 0.2	< 0.2	< 0.2
	EP6-09	0.2		< 0.2	< 0.2	< 0.2	< 0.2
	K6-01S	0.2		< 0.2	< 0.2	< 5	< 5
	K6-19	0.2		< 0.2	< 0.2	< 5	< 5
	K6-36	0.2		[(b)]	< 0.2	< 5	< 5
Radioactivity (Bq/L)							
Tritium	EP6-06	3.7	740	-1.5	-1.4	0.4	-1.1
	EP6-08	3.7		-2.1	-0.2	-0.5	0.7
	EP6-09	3.7		0.3	-1.8	0.9	0.2
	K6-01S	3.7		8.8	5.1	7.9	10.3
	K6-19	3.7		8.3	8.4	13.8	12.0
	K6-36	88		57.4	55.1	58.8	57.7
Uranium (total)	EP6-06	0.13	0.74	0.009	0.011	0.011	0.015
	EP6-08	0.06		0.047	0.045	0.048	0.029
	EP6-09	0.14		0.063	0.081	0.079	0.079
	K6-01S	1.00		0.140	0.169	0.151	0.167
	K6-19	0.27		0.114	0.128	0.113	0.102
	K6-36	0.05		0.040	0.040	0.038	0.034
Gross alpha	EP6-06	0.29	0.56	0.022	-0.025	-0.032	0.004
	EP6-08	0.15		0.003	0.010	-0.017	0.003
	EP6-09	0.18		0.359,<0.074[(c)]	0.034	0.007	0.053
	K6-01S	0.95		0.134	0.070	0.084	0.158
	K6-19	0.34		0.057	0.077	0.028	0.029
	K6-36	0.07		0.030	0.004	0.015	0.003
Gross beta	EP6-06	0.79	1.85	0.297	0.286	0.220	0.269
	EP6-08	0.79		0.293	0.437	0.363	0.459
	EP6-09	0.79		0.611	0.411	0.313	0.429
	K6-01S	2.13		0.696	0.744	0.729	0.773
	K6-19	0.79		0.288	0.274	0.329	0.381
	K6-36	0.97		0.269	0.298	0.307	0.259
Volatile organic compounds (μg/L, EPA method 601 or 624)							
Benzene	EP6-06	0.5	1	< 0.5	< 0.5	< 1	< 1
	EP6-08	0.5		< 0.5	< 0.5	< 0.5	< 1
	EP6-09	0.5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	0.5		< 0.5	< 0.5	< 1	< 1
	K6-19	0.5		< 0.5	< 0.5	< 1	< 1
	K6-36	0.5		< 0.5	< 0.5	< 1	< 1

Table A-1. Pit 6 post-closure monitoring plan constituents of concern (COCs) detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2005.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
Carbon disulfide	EP6-06	5	none	< 0.5	< 0.5	< 1	< 1
	EP6-08	5		< 0.5	< 0.5	< 0.5	< 1
	EP6-09	5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	5		< 0.5	< 0.5	< 0.5	< 1
	K6-19	5		< 0.5	< 0.5	< 0.5	< 1
	K6-36	5		< 0.5	< 0.5	< 0.5	< 1
Chloroform	EP6-06	0.5	100	< 1	< 1	< 1	< 1
	EP6-08	1.0		< 1	< 1	< 1	< 1
	EP6-09	0.5		< 1	< 1	< 1	< 1
	K6-01S	0.5		< 1	< 1	< 1	< 0.5
	K6-19	1.5		< 1	< 1	< 1	< 0.5
	K6-36	0.5		< 1	< 1	< 1	< 0.5
1,2-dichloroethane	EP6-06	0.5	0.5	< 0.5	< 0.5	< 1	< 1
	EP6-08	0.5		< 0.5	< 0.5	< 0.5	< 1
	EP6-09	0.5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-36	0.5		< 0.5	< 0.5	< 0.5	< 0.5
Cis-1,2-dichloroethene	EP6-06	0.5	6	< 0.5	< 0.5	< 1	< 1
	EP6-08	0.5		< 0.5	< 0.5	< 0.5	< 1
	EP6-09	0.5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	7.0		2.6	2.2	2.4	2
	K6-19	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-36	0.5		< 0.5	< 0.5	< 0.5	< 0.5
Ethyl benzene	EP6-06	0.5	700	< 0.5	< 0.5	< 1	< 1
	EP6-08	0.5		< 0.5	< 0.5	< 0.5	< 1
	EP6-09	0.5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	0.5		< 0.5	< 0.5	< 1	< 1
	K6-19	0.5		< 0.5	< 0.5	< 1	< 1
	K6-36	0.5		< 0.5	< 0.5	< 1	< 1
Methylene chloride	EP6-06	1	5	< 1	< 1	< 1	< 1
	EP6-08	1		< 1	< 1	< 1	< 1
	EP6-09	1		< 1	< 1	< 1	< 1
	K6-01S	1		< 1	< 1	< 3	< 3
	K6-19	1		< 1	< 1	< 3	< 3
	K6-36	1		< 1	< 1	< 3	< 3
Tetrachloroethene	EP6-06	0.5	5	< 0.5	< 0.5	< 1	< 1
(PCE)	EP6-08	1.6		0.83	0.97	0.77	< 1
	EP6-09	0.5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-36	1.0		0.68	0.64	0.6	< 0.5
Toluene	EP6-06	0.5	150	< 0.5	< 0.5	< 1	< 1
	EP6-08	0.5		< 0.5	< 0.5	< 0.5	< 1
	EP6-09	0.5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	0.5		< 0.5	< 0.5	< 1	< 1
	K6-19	0.5		< 0.5	< 0.5	< 1	< 1
	K6-36	0.5		< 0.5	< 0.5	< 1	< 1

Table A-1. Pit 6 post-closure monitoring plan constituents of concern (COCs) detection monitoring wells, SLs, MCLs, and quarterly analytical results for 2005.

				Quarter			
COC (units)	**Well**	**SL**	**MCL**	**First**	**Second**	**Third**	**Fourth**
1,1,1-trichloroethane	EP6-06	0.5	200	< 0.5	< 0.5	< 1	< 1
	EP6-08	0.5		< 0.5	< 0.5	< 0.5	< 1
	EP6-09	0.5		< 0.5	< 0.5	< 0.5	< 1
	K6-01S	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-19	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-36	0.5		< 0.5	< 0.5	< 0.5	< 0.5
Trichloroethene (TCE)	EP6-06	0.5	5	< 0.5	< 0.5	< 0.5	< 0.5
	EP6-08	0.5		< 0.5	< 0.5	< 0.5	< 0.5
	EP6-09	17		6	6	6.4	5.7
	K6-01S	1.5		< 0.5	< 0.5	< 0.5	< 0.5
	K6-19	13		1.3	3.4	3.3	3.1
	K6-36	2.1		1.2	1.1	0.8	1
Xylenes (total)	EP6-06	1	1750	< 1	< 1	< 2	< 2
	EP6-08	1		< 1	< 1	< 1	< 2
	EP6-09	1		< 1	< 1	< 1	< 2
	K6-01S	1		< 1	< 1	< 2	< 2
	K6-19	1		< 1	< 1	< 2	< 2
	K6-36	1		< 1	< 1	< 2	< 2
Perchlorate (μg/L)	EP6-06	4.7	6 [(a)]	< 4	< 4	< 4	< 4
	EP6-08	4		< 4	< 4	< 4	< 4
	EP6-09	4		4.6	4.4	6.9	4
	K6-01S	4		< 4	< 4	< 4	< 4
	K6-19	27.5		< 4	< 4	< 4	< 4
	K6-36	14.4		< 4	< 4	< 4	< 4

(a) California state action level. *Concluded*

(b) Sample exceeded hold time.

(c) Due to delays in sampling and analysis a duplicate QA sample is presented (see text for details).

(d) The analytical laboratory reported incorrect reporting limits, LLNL is attempting to correct this.

Table A-2. Pit 6 detection monitoring quarterly ground water physical parameters for 2005.

			Parameters				
Detection well	Quarter 2005	Date sampled	GWE [(a)] (ft)	Temp. (°C)	pH (pH units)	Sp. cond. (μmho/cm)	TDS[(b)] (mg/L)
EP6-06	1	8-Mar-05	658.42	21.5	7.27	1291	860
	2	4-May-05	659.11	22.6	7.44	1288	880
	3	27-Jul-05	659.90	23.0	7.56	1281	840
	4	25-Oct-05	660.57	22.4	7.65	1294	860
EP6-08	1	8-Mar-05	658.42	21.5	7.27	1291	860
	2	28-Apr-05	657.71	20.7	7.57	1094	710
	3	21-Jul-05	657.88	22.6	7.38	1136	700
	4	19-Oct-05	656.75	22.0	7.36	1108	740
EP6-09	1	7-Mar-05	664.06	21.4	7.77	1472	980
	2	4-May-05	664.81	21	7.63	1500	990
	3	21-Jul-05	664.95	22.0	7.71	1498	980
	4	25-Oct-05	664.73	21.2	7.74	1486	980
K6-01S	1	3-Mar-05	663.89	21.9	7.12	3373	2600
	2	4-May-05	664.72	22.2	6.91	4146	3100
	3	7-Jul-05	664.93	22.6	6.94	4143	3200
	4	6-Oct-05	664.86	21.9	7.1	4176	3000
K6-19	1	8-Mar-05	663.90	20.8	7.51	1159	750
	2	3-May-05	663.94	22.1	7.53	1135	660
	3	7-Jul-05	664.10	23.5	7.73	1142	730
	4	19-Oct-05	663.99	23.4	7.8	1161	740
K6-36	1	2-Mar-05	657.83	21.3	7.49	1064	720
	2	4-May-05	657.60	22.9	7.73	1097	700
	3	28-Jul-05	DRY	DRY	DRY	DRY	DRY
	4	27-Oct-05	655.75	22.3	7.76	1083	700

(a) Ground water elevation (water table elevation in feet above mean sea level).

(b) Total dissolved solids.

Appendix B

Tables of Ground Water Measurements

for Corrective Action Monitoring Wells

Table B-1. Pit 6 ground water elevations, during fourth quarter 2005.

Well	Date sampled	Ground water elevation (ft. above MSL)
BC6-10	27-Oct-05	659.50
BC6-13	27-Oct-05	DRY
CARNRW1	12-Oct-05	631.98
CARNRW1	12-Oct-05	631.98
CARNRW3	12-Oct-05	668.36
CARNRW4	12-Oct-05	639.22
EP6-07	27-Oct-05	656.25
K6-01	27-Oct-05	664.76
K6-01S	6-Oct-05	664.86
K6-03	27-Oct-05	656.30
K6-04	27-Oct-05	657.17
K6-14	27-Oct-05	658.27
K6-15	27-Oct-05	DRY
K6-16	27-Oct-05	660.70
K6-17	12-Oct-05	656.75
K6-18	27-Oct-05	660.42
K6-21	27-Oct-05	DRY
K6-22	12-Oct-05	647.43
K6-23	27-Oct-05	656.96
K6-24	27-Oct-05	655.46
K6-25	27-Oct-05	660.75
K6-26	27-Oct-05	656.00
K6-27	27-Oct-05	654.79
K6-32	27-Oct-05	657.41
K6-33	27-Oct-05	650.59
K6-34	12-Oct-05	650.59
K6-35	27-Oct-05	657.15
K6-36	27-Oct-05	655.75
K6-36	27-Oct-05	655.75
W-33C-01	24-Oct-05	635.01
W-34-01	27-Oct-05	676.46
W-34-02	27-Oct-05	656.46

Table B-2. Pit 6 volatile organic compounds (VOCs) detected during the fourth quarter 2005.

VOCs detected	Well	Date sampled	Type	Result (µg/L)
VOCs (EPA 601 or EPA 624)				
1,2-Dichloroethene (total)	K6-01S	6-Oct-05	RTN	2
Bromodichloromethane	CARNRW2	12-Oct-05	DUP	0.9
Bromodichloromethane	CARNRW2	12-Oct-05	RTN	0.95
Bromodichloromethane	CARNRW2	14-Dec-05	RTN	0.79
Bromodichloromethane	CARNRW3	9-Nov-05	DUP	2.6
Bromodichloromethane	CARNRW3	9-Nov-05	RTN	2
Bromoform	CARNRW2	12-Oct-05	DUP	20
Bromoform	CARNRW2	12-Oct-05	RTN	22
Bromoform	CARNRW2	14-Dec-05	RTN	5.4
Bromoform	CARNRW3	9-Nov-05	DUP	15
Bromoform	CARNRW3	9-Nov-05	RTN	15
Chloroform	CARNRW2	14-Dec-05	RTN	0.66
Chloroform	CARNRW3	9-Nov-05	DUP	1.1
Chloroform	CARNRW3	9-Nov-05	RTN	0.9
Dibromochloromethane	CARNRW2	12-Oct-05	DUP	3.4
Dibromochloromethane	CARNRW2	12-Oct-05	RTN	3.4
Dibromochloromethane	CARNRW2	14-Dec-05	RTN	2.2
Dibromochloromethane	CARNRW3	9-Nov-05	DUP	8.9
Dibromochloromethane	CARNRW3	9-Nov-05	RTN	7.2
Total Trihalomethanes	CARNRW2	12-Oct-05	RTN	27
Total Trihalomethanes	CARNRW2	14-Dec-05	RTN	9
Total Trihalomethanes	CARNRW3	9-Nov-05	RTN	25
Trichloroethene	EP6-09	25-Oct-05	RTN	5.7
Trichloroethene	K6-19	19-Oct-05	DUP	3
Trichloroethene	K6-19	19-Oct-05	RTN	3.1
Trichloroethene	K6-36	27-Oct-05	RTN	1
cis-1,2-Dichloroethene	K6-01S	6-Oct-05	RTN	2

Table B-3. Pit 6 tritium activity, fourth quarter 2005.

Well	Date sampled	Activity (pCi/L)	Activity (Bq/L)
CARNRW1	12-Oct-05	< 200	< 7.4
CARNRW1	12-Oct-05	108	4.0
CARNRW1	9-Nov-05	< 100	< 3.7
CARNRW1	9-Nov-05	< 200	< 7.4
CARNRW1	14-Dec-05	< 200	< 7.4
CARNRW1	14-Dec-05	< 100	< 3.7
CARNRW2	12-Oct-05	< 200	< 7.4
CARNRW2	12-Oct-05	< 100	< 3.7
CARNRW2	9-Nov-05	< 200	< 7.4
CARNRW2	14-Dec-05	< 200	< 7.4
CARNRW2	14-Dec-05	< 100	< 3.7
CARNRW2	9-Nov-05	< 100	< 3.7
CARNRW3	12-Oct-05	< 200	< 7.4
CARNRW3	12-Oct-05	< 100	< 3.7
CARNRW3	14-Dec-05	< 100	< 3.7
CARNRW3	14-Dec-05	< 200	< 7.4
CARNRW3	9-Nov-05	< 200	< 7.4
CARNRW3	9-Nov-05	< 100	< 3.7
CARNRW4	12-Oct-05	< 200	< 7.4
CARNRW4	12-Oct-05	192	7.1
CARNRW4	14-Dec-05	< 100	< 3.7
CARNRW4	14-Dec-05	< 200	< 7.4
CARNRW4	9-Nov-05	< 200	< 7.4
CARNRW4	9-Nov-05	< 100	< 3.7
EP6-06	25-Oct-05	< 100	< 3.7
EP6-08	19-Oct-05	< 100	< 3.7
EP6-09	25-Oct-05	< 100	< 3.7
K6-01S	6-Oct-05	278	10.3
K6-17	12-Oct-05	< 200	< 7.4
K6-17	12-Oct-05	< 100	< 3.7
K6-19	19-Oct-05	323	12.0
K6-19	19-Oct-05	333	12.3
K6-22	12-Oct-05	< 100	< 3.7
K6-34	12-Oct-05	< 100	< 3.7
K6-36	27-Oct-05	1560	57.7
W-PIT6-1819	12-Oct-05	156	5.8

Table B-4. Pit 6 perchlorate and nitrate in ground water during fourth quarter 2005.

Well	Date sampled	Type	Perchlorate (μg/L)	Nitrate (as NO_3) (mg/L)
CARNRW1	12-Oct-05	DUP	< 4	0.63
CARNRW1	12-Oct-05	RTN	< 4	0.81
CARNRW1	8-Nov-05	RTN	< 4	< 0.5
CARNRW1	9-Nov-05	RTN	< 4	< 2
CARNRW1	14-Dec-05	RTN	< 4	< 0.5
CARNRW2	12-Oct-05	DUP	< 4	< 0.1
CARNRW2	12-Oct-05	RTN	< 4	< 0.5
CARNRW2	9-Nov-05	DUP	< 4	< 2
CARNRW2	9-Nov-05	RTN	< 4	< 0.5
CARNRW2	14-Dec-05	RTN	< 4	< 0.5
CARNRW3	12-Oct-05	DUP	< 4	< 0.1
CARNRW3	12-Oct-05	RTN	< 4	< 0.5
CARNRW3	9-Nov-05	DUP	< 4	< 2
CARNRW3	9-Nov-05	RTN	< 4	< 0.5
CARNRW3	14-Dec-05	RTN	< 4	< 0.5
CARNRW4	12-Oct-05	DUP	< 4	< 0.1
CARNRW4	12-Oct-05	RTN	< 4	< 0.5
CARNRW4	9-Nov-05	DUP	< 4	< 2
CARNRW4	9-Nov-05	RTN	< 4	< 0.5
CARNRW4	14-Dec-05	RTN	< 4	< 0.5
EP6-06	25-Oct-05	RTN	< 4	< 0.5
EP6-08	19-Oct-05	RTN	< 4	< 0.5
EP6-09	25-Oct-05	RTN	4	3.2
K6-01S	6-Oct-05	RTN	< 4	< 0.1
K6-19	19-Oct-05	DUP	< 4	< 0.1
K6-19	19-Oct-05	RTN	< 4	< 0.1
K6-36	27-Oct-05	RTN	< 4	< 0.1

Table B-5. Pit 6 monitoring locations, monitoring functions, associated monitoring programs, COCs, monitoring frequencies, and fourth quarter 2005 sampling summary.

Monitoring location	Monitoring function	Monitoring program	COCs[(a)] (sampling frequency)	COCs analyzed	Reason(s), if not completed
K6-17	guard well	CAMP	P (Q), S (SA)	P	
K6-22	guard well	CAMP	P (Q), S (SA)	P	
K6-34	guard well	CAMP	P (Q), S (SA)	P	
W-PIT6-1819	guard well	CAMP	P (Q), S (SA)	P	
SPRING7	plume tracking spring	CAMP	P (SA), S (A)	none	not scheduled
SPRING15	plume tracking spring	CAMP	P (SA), S (A)	none	not scheduled
BC6-10	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
BC6-13	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
EP6-07	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-01	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-03	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-04	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-14	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-15	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-16	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-18	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-21	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-23	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-24	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-25	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-26	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-27	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-32	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-33	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
K6-35	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
W-33C-01	plume tracking well	CAMP	P (SA), S (A)	none	not scheduled
EP6-06	release detection well	DMP	All (Q)	All	
EP6-08	release detection well	DMP	All (Q)	All	
EP6-09	release detection well	DMP	All (Q)	All	
K6-01S	release detection well	DMP	All (Q)	All	
K6-19	release detection well	DMP	All (Q)	All	
K6-36	release detection well	DMP	All (Q)	All	
CARNRW1	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW2	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW3	water supply well	CAMP	P (M), S (M)	P,S	
CARNRW4	water supply well	CAMP	P (M), S (M)	P,S	

(a) P means the primary COCs tritium and VOCs. S means the secondary COCs perchlorate and nitrate. All means all DMP COCs (see **Table C-1** for a list). (M) means sampled monthly. (Q) means sampled quarterly. (SA) means sampled semiannually (done first and third quarters of year). (A) means sampled annually (done first quarter of year).

Appendix C

Statistical Methods

for Detection Monitoring

Appendix C

Statistical Methods for Detection Monitoring

Monitoring and reporting provisions of the CERCLA closure and post-closure plan for the Pit 6 landfill require the use of statistical methods from the *California Code of Regulations* (CCR), Title 23, Division 3, Chapter 15, Section 2550.7 (Ferry *et al*. 1998).

We use statistically determined limits of concentration (SLs) to detect potential releases of constituents of concern (COCs) to ground water from solid wastes contained in the Pit 6 landfill. We employ two statistical methods, prediction intervals (PIs) and control charts (CCs), to generate SLs. Both methods are sensitive to COC concentration increases. Both methods are cost-effective, requiring only one measurement of a COC per quarter per monitoring well.

We prefer the PI method when COC concentrations in ground water are similar upgradient and downgradient from the monitored unit. We use parametric PI methods when the upgradient COC concentration data are all above the detection limit and the data are approximately normally distributed. We may use parametric methods on log-transformed data, if the transformed data follow a normal distribution. Nonparametric PI methods are more effective when the data cannot be transformed to a normal distribution, or when they contain nondetections.

When the concentration of a COC is spatially variable in the vicinity of a monitored unit, we develop a control chart for each downgradient monitoring well. The control chart compares each new quarterly COC measurement with its concentration history for that well.

Wherever sufficient historical detections exist, we calculate an SL such that any future measurement has approximately a 1-in-100 chance of exceeding the SL, when no change in concentration has actually occurred. This yields a statistical test with a significance level of approximately 0.01. Where historical detections exist, but nondetections constitute part of the data, we set the SL equal to the highest concentration measured. If historical analyses of a COC show all nondetections, then we set the SL equal to the analytical reporting limit (RL). When a routine COC measurement exceeds an SL, we perform two discrete

retests. This method of data verification is in accordance with CCR Title 23, Chapter 15, Section 2550.7.

Constituents of Concern

COCs were identified for monitoring in the ground water at the Pit 6 landfill prior to its closure (Ferry *et al.* 1998). COCs, as defined by CCR Title 22, Chapter 15, are waste constituents, their reaction products, or hazardous constituents that are reasonably expected to be in or derived from waste buried in Pit 6. The current COCs for Pit 6 are listed in **Table C-1** below.

Table C-1. Pit 6 COCs, typical analytical reporting limit (RL), concentration limit (CL)[a] and statistical limit (SL) for each of the six detection monitoring wells.

Constituent of concern (COC)	Typical analytical RL (units)	Well EP6-06 CL; SL	Well EP6-08 CL; SL	Well EP6-09 CL; SL	Well K6-01S CL; SL	Well K6-19 CL; SL	Well K6-36 CL; SL
1,1,1-TCA	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
1,2-DCA	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Cis-1,2-DCE	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	5.4; 7.0	<RL; RL	<RL; RL
Chloroform	0.5 µg/L	<RL; RL	0.1; 1.0	<RL; RL	<RL; RL	0.2; 1.5	<RL; RL
Methylene chloride	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
PCE	0.5 µg/L	<RL; RL	0.4; 1.6	<RL; RL	<RL; RL	<RL; RL	0.5; 1.0
TCE	0.5 µg/L	<RL; RL	<RL; RL	14; 17	1.1; 1.5	8.2; 13	0.8; 2.1
Benzene	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Ethylbenzene	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Toluene	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Total xylenes	1.0 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Beryllium	0.5 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Mercury	0.2 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Carbon disulfide	5.0 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL
Perchlorate	3.0 µg/L	<RL; RL	<RL; RL	<RL; RL	<RL; RL	10.2; 27.5	5.3; 14.4
Tritium	100 pCi/L	RL; RL	<RL; RL	<RL; RL	<RL; RL	<RL; RL	2060; 2390
Uranium (total)	0.5 pCi/L	1.9; 3.6	1.2; 1.5	2.1; 3.7	6.6; 27	3.2; 7.2	0.5; 1.4
Gross alpha [b]	2 pCi/L	2.7; 7.7	0.9; 4.0	1.0; 4.9	7.0; 26	2.0; 9.2	<RL; RL
Gross beta [b]	2 pCi/L	8.6; 21	8.6; 21	8.6; 21	14; 58	8.6; 21	9.8; 26

(a) CL (concentration limit) is equivalent to the background concentration of a COC.

(b) Gross alpha and gross beta are surrogates for ^{125}Sb, ^{137}Cs, ^{60}Co, ^{22}Na, ^{90}Sr, ^{204}Tl, and ^{232}Th.

Chlorinated VOCs (including TCE, PCE, 1,2-DCA, 1,1,1-TCA, methylene chloride, chloroform, benzene, toluene, ethylbenzene, and total xylenes) were detected historically in ground water and/or in soil adjacent to Pit 6. These VOCs are COCs.

Beryllium and mercury are COCs because they are listed in the waste disposal records for Pit 6.

Nine radionuclide COCs are associated with waste buried in Pit 6. They are ^{125}Sb, ^{137}Cs, ^{60}Co, ^{22}Na, ^{90}Sr, ^{204}Tl, ^{232}Th, ^{238}U, and tritium. Gross alpha and gross beta radioactivity are used as surrogates for seven of these nuclides, but not for uranium and tritium, which are measured separately (**Table C-1**).

A minor tritium release occurred prior to closure of Pit 6 and is the object of a continuing LLNL CERCLA investigation. The detection monitoring well BC6-12 was destroyed during year 2000, because it was screened across two water-bearing zones and could have provided a conduit for tritium in the shallower zone to contaminate ground water in the deeper zone. Well BC6-12 was replaced by well K6-36, which was constructed adjacent to it. Well K6-36 is screened only in the shallow water-bearing zone. Our calculated COC SLs for replacement well K6-36 are shown (**Table C-1)**.

A post-closure LLNL CERCLA study detected perchlorate in ground water downgradient of Pit 6. Consequently, perchlorate was added to the COC list and we have calculated SLs for this chemical (**Table C-1**).

Pesticides were not detected over an 18-month period (6 quarterly sampling events) following pit closure and were removed from the COC list.

Phthalates were not designated as COCs, because they were rarely detected prior to pit closure. However, since post-closure monitoring began in 1998, we have detected bis(2-ethylhexyl)phthalate (also known as di[2-ethylhexyl]phthalate, or DEHP) in ground water both upgradient and downgradient from Pit 6.

Table C-2 lists COCs that have indicated statistically significant evidence of release to ground water since post-closure monitoring began in 1998. **Table C-2** also lists the date of our 7-day letter notification to CVRWQCB and the status of any additional investigation of the COC. Note that 1,2-DCA has not been detected since 1998.

Table C-2. Pit 6 COCs showing statistical evidence of post-closure release.

COC	Date of 7-day letter report	Status of release investigation
1,2-DCA	10/13/98[a]	Transferred to ERD[b]
Perchlorate	11/08/02[c]	Retests did not confirm a release
Uranium	05/10/04[d]	Retest indicates a natural source

(a) Galles, H. L., to S. Timm (1998), Letter: *Statistically Significant Evidence for a Release of 1,2-Dichloroethane from Pit 6* (WGMG98:282, October 13, 1998).

(b) LLNL Environmental Restoration Division.

(c) Raber, E., to T. Park, K. Setian, and S. Timm (2002), Letter*: Statistically Significant Evidence for a Release of Perchlorate from Lawrence Livermore National Laboratory Experimental Test Site (Site 300) Pit 6* (WGMG02-182, November 8, 2002).

(d) Raber, E., to T. Park, K. Setian, and S. Timm (2004), Letter: *Statistically Significant Evidence for a Release of Uranium from Lawrence Livermore National Laboratory Experimental Test Site (Site 300) Pit 6* (WGMG04-055, May 10, 2004).

Appendix D

Changes in Monitoring Programs or Methods

Appendix D

Changes in Monitoring Programs or Methods

LLNL implemented a compliance monitoring program during the second quarter of 1998 for the CERCLA-closed Pit 6 landfill at Site 300. The program is described in detail in Ferry *et al.* 1998.

During 2000, two new monitoring wells, designated K6-35 and K6-36, replaced monitoring wells BC6-11 and BC6-12, which were destroyed by grouting. Well K6-36, which is screened in the first (shallower) of two water-bearing zones, replaced well BC6-12 for release detection. Well K6-35, screened in the next deeper water-bearing zone, is used for corrective-action assessment.

By request of the CVRWQCB, we added perchlorate to the list of Pit 6 COCs during the third quarter of 2000.

By request of the CVRWQCB, since the third quarter of 2000, we have provided a table of information (**Table B-5)** that lists the Pit 6 CERCLA monitoring wells, their monitoring program assignments, their sampling frequencies, the COCs they monitor, and a reason if they were not sampled during the reported quarter.

During 2001, quarterly tritium monitoring was expanded to include CERCLA well K6-33 and the private, off-site, water supply wells designated CARNRW1 and CARNRW2. During 2002 a new CERCLA guard well was completed downgradient from Pit 6 adjacent to the Site 300 boundary. This well is identified as W-PIT6-1819.

Beginning January 1, 2003 the CAMP sampling schedule and COCs have changed as described in the *Compliance Monitoring Plan/Contingency Plan for Interim Remedies at Lawrence Livermore National Laboratory Site 300* (Ferry, *et al.* 2002). An expanded set of CAMP wells and springs will be sampled semiannually for tritium and VOCs, and annually for nitrate and perchlorate, while DMP well monitoring remains essentially unchanged. However, upgradient wells K6-03, K6-04, K6-15, and K6-32, which were formerly sampled quarterly for all the DMP COCs listed in **Table C-1**, are now designated to be CAMP plume-tracking wells and are sampled semiannually for tritium and VOCs and annually for nitrate and perchlorate only. As of forth quarter 2004 VOCs have been reported as Total VOCs (TVOCs) to be consistent with other reports.

Appendix E

Quality Assurance Sample Results

Table E-1. Quality assurance samples from Pit 6 during the fourth quarter 2005.

Date Sampled: K6-19 on 19-OCT-05 and the Field Blank on 6-OCT-05

	QA Samples			
	K6-19	K6-19	PIT6	
Constituent	routine	duplicate	field blank	units
Total dissolved solids (TDS)	740	740	< 10	mg/L
Beryllium	< 0	< 0	< 0	mg/L
Mercury	< 0.01	< 0.01	< 0.01	mg/L
Nitrate (as NO3)	< 0.1	< 0.1	< 0.1	mg/L
Perchlorate	< 4	< 4	< 4	ug/L
1,1,1-Trichloroethane	< 0.5	< 0.5	< 0.5	ug/L
1,1,2,2-Tetrachloroethane	< 0.5	< 0.5	< 0.5	ug/L
1,1,2-Trichloroethane	< 0.5	< 0.5	< 0.5	ug/L
1,1-Dichloroethane	< 0.5	< 0.5	< 0.5	ug/L
1,1-Dichloroethene	< 0.5	< 0.5	< 0.5	ug/L
1,2-Dichlorobenzene	< 0.5	< 0.5	< 0.5	ug/L
1,2-Dichloroethane	< 0.5	< 0.5	< 0.5	ug/L
1,2-Dichloroethene (total)	< 0.5	< 0.5	< 0.5	ug/L
1,2-Dichloropropane	< 0.5	< 0.5	< 0.5	ug/L
1,3-Dichlorobenzene	< 0.5	< 0.5	< 0.5	ug/L
1,4-Dichlorobenzene	< 0.5	< 0.5	< 0.5	ug/L
cis-1,2-Dichloroethene	< 0.5	< 0.5	< 0.5	ug/L
cis-1,3-Dichloropropene	< 0.5	< 0.5	< 0.5	ug/L
2-Butanone	< 10	< 10	< 10	ug/L
2-Chloroethylvinylether	< 0.5	< 0.5	< 0.5	ug/L
2-Hexanone	< 10	< 10	< 10	ug/L
4-Methyl-2-pentanone	< 10	< 10	< 10	ug/L
Acetone	< 10	< 10	< 10	ug/L
Benzene	< 1	< 1	< 1	ug/L
Bromodichloromethane	< 0.5	< 0.5	< 0.5	ug/L
Bromoform	< 0.5	< 0.5	< 0.5	ug/L
Bromomethane	< 0.5	< 0.5	< 0.5	ug/L
Carbon disulfide	< 1	< 1	< 1	ug/L
Carbon tetrachloride	< 0.5	< 0.5	< 0.5	ug/L
Chlorobenzene	< 0.5	< 0.5	< 0.5	ug/L
Chloroethane	< 0.5	< 0.5	< 0.5	ug/L
Chloroform	< 0.5	< 0.5	1.7	ug/L
Chloromethane	< 0.5	< 0.5	< 0.5	ug/L
Dibromochloromethane	< 0.5	< 0.5	< 0.5	ug/L
Dibromomethane	< 1	< 1	< 1	ug/L
Dichlorodifluoromethane	< 0.5	< 0.5	< 0.5	ug/L
Ethylbenzene	< 1	< 1	< 1	ug/L
Freon 113	< 1	< 1	< 1	ug/L
Methylene chloride	< 3	< 3	< 3	ug/L

Table E-1. Quality assurance samples from Pit 6 during the fourth quarter 2005.

Date Sampled: K6-19 on 19-OCT-05 and the Field Blank on 6-OCT-05

	QA Samples			
	K6-19	K6-19	PIT6	
Constituent	**routine**	**duplicate**	**field blank**	**units**
Styrene	< 1	< 1	< 1	ug/L
Tetrachloroethene	< 0.5	< 0.5	< 0.5	ug/L
Toluene	< 1	< 1	< 1	ug/L
Total xylene isomers	< 2	< 2	< 2	ug/L
trans-1,2-Dichloroethene	< 0.5	< 0.5	< 0.5	ug/L
trans-1,3-Dichloropropene	< 0.5	< 0.5	< 0.5	ug/L
Trichloroethene	3.1	3	< 0.5	ug/L
Trichlorofluoromethane	< 0.5	< 0.5	< 0.5	ug/L
Vinyl chloride	< 0.5	< 0.5	< 0.5	ug/L
Tritium	12.0 ± 2.5	12.3 ± 2.6	2.5 ± 2.1	Bq/L
Gross alpha	0.029 ± 0.044	0.074 ± 0.052	0.002 ± 0.006	Bq/L
Gross beta	0.381 ± 0.070	0.354 ± 0.074	-0.005 ± 0.032	Bq/L
Uranium total	0.102 ± 0.010	0.102 ± 0.010	0.001 ± 0.001	Bq/L

Appendix F

Survey Results for Fixed Elevation Markers

Table F-1. Comparison of Pit 6 cap fixed marker elevations from annual surveys (rounded to 0.01 foot).

Marker	1998[a]	2004	2004 - 1998
A-1	720.34	720.33	-0.01
A-2	720.87	720.88	0.01
A-3	721.47	721.51	0.03
A-4	722.31	722.33	0.02
A-5	722.84	722.76	*-0.08* [b]
A-6	721.95	721.99	0.03
B-1	712.53	712.59	0.06
B-2	711.83	711.86	0.03
B-3	712.32	712.34	0.03
B-4	712.31	712.32	0.01
B-5	714.17	714.21	0.04
C-1	708.99	709.03	0.04
C-2	708.21	708.23	0.02
C-3	710.31	710.22	-0.09 [c]
C-4	708.09	708.09	0.00
C-5	708.63	708.60	-0.03
D-1	702.56	702.60	0.04
D-2	701.73	701.76	0.03
D-3	701.33	701.34	0.02
D-4	700.93	700.94	0.01
D-5	704.91	704.91	0.00
D-6	705.10	705.11	0.01

[a] Baseline survey.

[b] Value constitutes the largest change observed to occur during calendar year 2005 most likely resulting from fire fighting activities.

[c] This value experienced this change during 2001, the difference between calendar years 2004 and 2005 was -0.01 ft.

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